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(54) Title: COATED TURNING INSERT

(57) Abstract

The present invention discloses a coated turning insert particularly useful for turning of forged components in low alloyed steel. The insert is characterised by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating including an innermost layer of $TiC_xN_yO_z$ with columnar grains and a top layer of fine grained κ-Al_2O_3.

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Coated turning insert

The present invention relates to a coated cutting tool (cemented carbide insert) particularly useful for difficult cutting conditions such as turning in hot and cold forged low alloyed steel components like gear rings and axles used in the automotive industry and turning in stainless steel components like bars, tubes and flanges.

Stainless and low alloyed steels are materials which, in general, are difficult to machine with coated or uncoated cemented carbide tools. Smearing of work piece material onto the cutting edge and flaking of the coating often occur. The cutting conditions are particularly difficult during the turning of forged low alloyed components under wet conditions (using coolant). The hot forged skin (0.05-0.2 mm) is generally decarburized and thus softer than the bulk material due to a mainly ferritic structure. The cold forged skin (less than 0.05 mm) is cold-worked and, thus, harder due to a deformation hardening effect. Furthermore, the ferrite/pearlite bulk structure of such a material is often "ferrite-striated", i. e. the ferrite and pearlite are forming parallel stripes. This mixture of hard and soft materials makes the cutting conditions very difficult.

Further, when turning stainless and low alloyed steels by coated cemented carbide tools the cutting edge is worn by chemical wear, abrasive wear and by a so called adhesive wear. The adhesive wear is often the tool life limiting wear. Adhesive wear occurs when fragments or individual grains of the layers and later also parts of the cemented carbide are successively pulled away from the cutting edge as work piece chips are formed. Further, when wet turning is employed the wear may also be accelerated by an additional wear mechanism. Coolant and work piece material may penetrate

into the cooling cracks of the coatings. This penetration often leads to a chemical reaction between work piece material and coolant with the cemented carbide. The Co-binder phase may oxidise in a zone near the crack and along the interface between the coating and the cemented carbide. After some time coating fragments are lost piece by piece.

Swedish patent application 9501286-0 discloses a coated cutting insert particularly useful for dry milling of grey cast iron. The insert is characterised by a straight WC-Co cemented carbide body and a coating including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of fine grained α-Al_2O_3.

Swedish patent application 9502640-7 discloses a coated turning insert particularly useful for intermittent turning in low alloyed steel. The insert is characterised by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating including a layer of $TiC_xN_yO_z$ with columnar grains and a top layer of a finegrained, textured α-Al_2O_3.

It has surprisingly been found that by replacing the textured α-Al_2O_3-layer of the above mentioned patent applications with a κ-Al_2O_3-layer a cutting tool with excellent properties for turning stainless and forged components in low alloyed steel can be obtained.

Fig 1 is a micrograph in 5000X magnification of a coated insert according to the present invention in which

A - cemented carbide body
B - $TiC_xN_yO_z$-layer with equiaxed grains
C - $TiC_xN_yO_z$-layer with columnar grains
D - κ-Al_2O_3-layer with columnar like grains
E - TiN-layer (optional)

According to the present invention a turning tool insert is provided with a cemented carbide body of a

composition 5-11, preferably 5-8, most preferably 6.5-8, wt-% Co, 2-10, preferably 4-7.5, most preferably 5-7, wt-% cubic carbides of the metals from groups IVb, Vb or VIb of the periodic table of elements preferably Ti, Ta and/or Nb and balance WC. The grain size of the WC is about 2 µm. The cobalt binder phase is highly alloyed with W. The content of W in the binder phase can be expressed as the

CW-ratio= M_S /(wt-% Co · 0.0161),

where M_S is the measured saturation magnetization of the cemented carbide body in kA/m and

wt-% Co is the weight percentage of Co in the cemented carbide. The CW-ratio is a function of the W content in the Co binder phase. A low CW-ratio corresponds to a high W-content in the binder phase.

It has now been found according to the invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.76-0.92, preferably 0.80-0.90. The cemented carbide body may contain small amounts, <1 volume-%, of η-phase (M_6C), without any detrimental effect. In a preferred embodiment an about 15-35 µm thick surface zone depleted of cubic carbides and often enriched (generally more than 25 % enrichment) in binder phase can be present according to prior art such as disclosed in US 4,610,931. In this case the cemented carbide may contain carbonitride or even nitride.

The coating preferably comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with x+y+z=1, preferably z<0.5, with a thickness of 0.1-2 µm and with equiaxed grains with size <0.5 µm

- a layer of $TiC_xN_yO_z$ x+y+z=1, preferably with z=0 and x>0.3 and y>0.3, with a thickness of 3-15 µm, preferably 5-8 µm, with columnar grains and with an average diameter of <5 µm, preferably <2 µm. In an alternative

embodiment the outer part of this layer may contain oxygen, $z<0.5$

- a layer of a smooth, fine-grained (grain size 0.5-2 µm) Al_2O_3 consisting essentially of the κ-phase. However, the layer may contain small amounts, 1-3 vol-%, of the θ- or the α-phases as determined by XRD-measurement. The Al_2O_3-layer can have a thickness of 1-9 µm, preferably 1-3 µm or alternatively 4-8 µm and a surface roughness $R_{max} \leq 0.4$ µm over a length of 10 µm. Preferably, this Al_2O_3-layer is the outermost layer but it may also be followed by further layers such as a thin (about 0.1-1 µm) decorative layer of e g TiN.

According to the method of the invention a WC-Co-based cemented carbide body having a highly W-alloyed binder phase with a CW-ratio according to above and preferably with a binder phase enriched surface zone is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with $x+y+z=1$, preferably $z<0.5$, with a thickness of 0.1-2 µm, and with equiaxed grains with size <0.5 µm using known CVD-methods.

- a layer of $TiC_xN_yO_z$ $x+y+z=1$, preferably with $z=0$ or alternatively $z<0.5$ and $x>0.3$ and $y>0.3$, with a thickness of 3-15 µm, preferably 5-8 µm, with columnar grains and with an average diameter of <5 µm, preferably <2 µm, using preferably MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of 700-900 °C). The exact conditions, however, depend to a certain extent on the design of the equipment used.

- an outer layer of a smooth Al_2O_3-layer essentially consisting of κ-Al_2O_3 is deposited under conditions disclosed in EP-A-523 021. The Al_2O_3-layer has a thickness of 1-9 µm, preferably 1-3 µm or alternatively 4-8 µm, and a surface roughness $R_{max} \leq 0.4$ µm over a length of

10 µm. The smooth coating surface can be obtained by a gentle wet-blasting the coating surface with fine grained (400-150 mesh) alumina powder or by brushing the edges with brushes based on e g SiC as disclosed in Swedish patent application 9402543-4.

Example 1

A. Cemented carbide turning tool inserts of style CNMG 120408-PM with the composition 7.5 wt-% Co, 1.8 wt-% TiC, 0.5 wt-% TiN, 3.0 wt-% TaC, 0.4 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.88 were coated with a 0.5 µm equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 7 µm thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850 °C and CH_3CN as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.5 µm thick layer of Al_2O_3 was deposited using a temperature 970 °C and a concentration of H_2S dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.5 µm) decorative layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the Al_2O_3-layer consisted of 100 % κ-phase. The cemented carbide body had a surface zone about 25 µm thick, depleted from cubic carbides and with an about 30 % enrichment in binder phase. The coated inserts were brushed by a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light microscope showed that the thin TiN-layer had been brushed away only along the cutting edge leaving there a smooth, R_a=0.3 µm, Al_2O_3-layer surface. Coating thickness measurements on cross sectioned brushed samples showed no reduction of the coating along the edge line except for the outer TiN-layer that was removed.

B.) A strong competitive cemented carbide grade in style CNMG 120408 from an external leading carbide producer was selected for comparison in a turning test. The carbide had a composition of 9.8 wt-% Co, 0.2 wt-% TiC, 2.0 wt-% TaC, balance WC and a CW-ratio of 0.86. The insert had a coating consisting of a 5 µm TiCN-layer followed by a 1.5 µm thick Al_2O_3-layer and a 0.5 µm TiN-layer. Light microscope examination showed that the insert had not been smoothed along the edgeline after the coating step.

An insert from A was compared against an insert from B in a turning test in a hot forged ring gear (diameter 206 mm, in TSCM815H material). Each turning cycle performed on each component consisted of one facing cut, one longitudinal cut and one chamfering cut. The feed was 0.35 mm/rev and cutting speed around 230 m/min.

First, 150 components were machined with both insert A and B and obtained flank wear was measured and compared. Since the wear was much less developed on insert A it was allowed to cut further components, altogether 354 components. Obtained flank wear is shown in the table below:

	Number of components	measured flank wear, mm
insert A (according to the invention)	150	0.07
------"---------	354	0.08
insert B (external grade)	150	0.10

Microscope examination of the tested inserts showed tiny flaking on insert B while no visible flaking had occurred on insert A, not even after 354 machined components.

It is obvious from the obtained flank wear that insert A according to the invention is superior and possesses longer tool life.

Example 2

D.) A strong competitive cemented carbide grade in style CNMG 120408 from another external leading carbide producer was selected for comparison in a turning test. The chemical composition of the cemented carbide was: 7.6 wt-% Co, 2.4 wt-% TiC, 0.5 wt-% TiN, 2.4 wt-% TaC, 0.3 wt-% NbC and balance WC. The cemented carbide had a surface zone, about 20 µm thick, depleted from cubic carbides. The composition of the cemented carbide was similar to that of the invention but had a higher CW-ratio of 0.93 and a different coating which consisted of a 5 µm TiCN-layer followed by a 3.5 µm TiC-layer, a 1.5 µm Al_2O_3-layer and a 0.5 µm TiN-layer. Light microscope examination showed that the insert had not been smoothed along the edgeline after the coating step.

Inserts from A and D were compared in a facing turning test in a hot forged ring gear (outer diameter of 180 mm and inner diameter of 98 mm in a SCr420H material) with feed = 0.25-0.35 mm/rev and cutting speed = 220 m/min. The inserts were run to a predetermined flank wear value of 0.08 mm and the number of produced component was the evaluation criteria.

		Number of components	measured flank wear, mm
insert A (acc. to invent.)	edge 1	203	0.08
-------"--------	edge 2	226	0.08
insert D (external grade)		182	0.08

Example 3

C.) Cemented carbide turning tool inserts of style WNMG 080408-PM with the same composition and CW-ratio of 0.88 as insert A were coated according to A. XRD-measurement showed that the Al_2O_3-layer consisted of 100 % κ-phase. The inserts were brushed according to A.

E.) An insert in style WNMG 080408 from the same cemented carbide producer as in D and with the same CW-ratio, carbide composition and coating as in D was selected for comparison in a turning test. Light microscope examination showed that the insert had not been smoothed along the edgeline after the coating step.

Inserts from C and E were compared in a facing turning test of an forged axle (length of 487 mm and diameter of 27-65 mm, material 50CV4) with feed = 0.28-0.30 mm/rev and cutting speed = 160 m/min. Three axles were run per each cutting edge and the wear of the cutting edges was examined in a light microscope

insert C (acc. to invent.)	flank wear less than 0.07 mm no flaking
insert E (external grade)	flank wear less than 0.07 mm flaking and chipping along the edge

Example 4

F.) Cemented carbide turning tool inserts of style CNMG 120408-PM from the same batch as in A were coated according to Swedish patent application 9502640-7 with 0.5 equiaxed TiCN followed by a 7 µm thick layer TiCN with columnar grains, 1 µm equiaxed TiCN and a 4 µm thick 012-textured α-Al_2O_3. The inserts were wet-blasted using a water/Al_2O_3-slurry in order to smooth the coating surfaces.

G.) Cemented carbide turning tool inserts of style CNMG 120408-PM with the composition 6.5 wt-% Co and 8.8 wt-% cubic carbides (3.3 wt-% TiC, 3.4 wt-% TaC and 2.1 wt-% NbC) and balance WC were coated under the procedure given in A). The cemented carbide body had a CW-ratio = 1.0 and a surface zone about 23 µm thick depleted in cubic phase and enriched in binder phase. XRD-measurement showed that the Al_2O_3-layer consisted only of the κ-phase.

Inserts from A, F, G and B were compared in a turning test in a hot and cold forged ring gear in material SCr420H.

The ring had an outer diameter of 190 mm and an inner diameter of 98 mm. Each turning cycle performed on each component consisted of three facing cuts and one longitudinal cut. Feed = 0.25-0.40 mm/rev and cutting speed around 200 m/min. 170 components were machined and the wear of the cutting edges was examined.

insert A (acc. to invent.)	no visible flaking of the coating, flank wear less than 0.07 mm
insert F (CW-ratio = 0.88)	some removal of the coating along the cutting edge, flank wear less than 0.08 mm
insert G (CW-ratio = 1.0)	substantial flaking along the cutting edge and flank wear more than 0.10 mm
insert B (external)	some removal of coating along the cutting edge, flank wear less than 0.08 mm

Although insert F produced according to the Swedish patent application 9502640-7 generally performs superior when turning low alloyed steels it can not always compete with insert A produced according to the present invention when turning some hot and cold forged low alloyed steel components.

Example 5

H.) Inserts from the same batch as in A in Example 1 were coated according to the procedure given in Example 1 with the exception that the process time for the Al_2O_3 coating step was prolonged to 7.5 hours giving a 5.5 µm thick layer of Al_2O_3. A thin (0.5 µm) decorative layer of TiN was deposited on top using prior art technique.

I.) Inserts from the same batch as in H were coated with a 7 µm equiaxed layer of TiCN followed by a 5 µm thick layer of Al_2O_3-layer and a 0.5 µm top coating of TiN using prior art techniques. XRD-analysis showed that the Al_2O_3-layer consisted of a mixture of α- and κ-Al_2O_3, approximately in the ratio 30/70. Inserts from H and A were brushed after coating in order to remove the TiN-layer and smooth the cutting edge.

Inserts from H, A and H were tested in an intermittent longitudinal turning operation. The work piece material was a low alloyed low carbon steel(SCr420H) in the shape of a 22 mm thick ring with an outer diameter of 190 mm and an inner diameter of 30 mm. Each longitudinal passage over the ring thickness consisted of 22 in-cuts of one mm each. The number of passages over the ring thickness until flaking occurred was recorded for each insert.

Insert	number of passages before edge flaking
A.) acc. to the invention 1.5 µm Al_2O_3	240
H.) acc. to the invention 5.5 µm Al_2O_3	180
I.) acc. to prior art 5 µm Al_2O_3	40

Inserts from H and A were also compared in a cutting test in a ball-bearing steel (SKF25B, v=250 m/min, f=0.3 mm/r, depth of cut= 2 mm). In this test crater wear was predominant. The inserts were run for 15 min and the formed crater wear was measured as crater area in mm^2.

Insert	crater area, mm^2
A.) acc. to the invention 1.5 µm Al_2O_3	0.9
H.) acc. to the invention 5.5 µm Al_2O_3	0.5

From the test results above it is clear that insert I have inferior flaking resistance compared to insert H and A. Insert H show both good result with respect to crater wear resistance and flaking resistance. Insert A show the best flaking resistance and can be used in cutting operations demanding extremely high flaking resistance.

Example 6

H. A cemented carbide turning tool insert in style TNMG160408-MM with the composition of 7.5 wt-% Co, 1.8 wt-% TiC, 3.0 wt-% TaC, 0.4 wt-% NbC, balance WC and a CW-ratio of 0.88. The cemented carbide had a surface zone, about 25 µm thick, depleted from cubic carbides. The insert was coated with an innermost 0.5 µm equiaxed TiCN-layer with a high nitrogen content, corresponding to an estimated C/N ratio of 0.05, followed by a 7.2 µm thick layer of columnar TiCN deposited using MT-CVD technique. In subsequent steps during the same coating process a 1.2 µm layer of Al_2O_3 consisting of pure κ-phase according to procedure disclosed in EP-A-523 021. A thin, 0.5 µm, TiN layer was deposited, during the same cycle, on top of the Al_2O_3-layer. The coated insert was brushed by a SiC containing nylon straw brush after coating, removing the outer TiN layer on the edge.

I. A competitive cemented carbide turning tool insert in style TNMG160408 from an external leading cemented carbide producer was selected for comparison in a turning test. The carbide had a composition of 9.0 wt-% Co, 0.2 wt-% TiC, 1.7 wt-% TaC, 0.2 wt-% NbC, balance WC and a CW-ratio of 0.90. The insert had a coating consisting of 1.0 µm TiC, 0.8 µm TiN, 1.0 µm TiC and, outermost, 0.8 µm TiN. Examination in light optical microscope revealed no edge treatment subsequent to coating.

The inserts H and I were tested in longitudinal, dry, turning of a shaft in duplex stainless steel.

Feed 0.3 mm/rev, speed 140 m/min and depth of cut 2 mm. Total cutting time per component was 12 minutes.

Insert I got plastic deformation whereas insert H got some notch wear.

One edge of insert H according to the invention completed one component whereas four edges were required to finalise one component using insert I.

Claims

1. A cutting tool insert for turning of steel comprising a cemented carbide body and a coating characterised in that said cemented carbide body consists of WC, 5-11 wt-% Co and 2-10 wt-% cubic carbides of Ti, Ta and/or Nb and a highly W-alloyed binder phase with a CW-ratio of 0.76-0.92 and in that said coating comprises

- a first (innermost) layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 µm, and with equiaxed grains with size <0.5 µm

- a layer of $TiC_xN_yO_z$ with a thickness of 3-15 µm with columnar grains with a diameter of <5 µm

- an outer layer of a smooth, fine-grained (0.5-2 µm) κ-Al_2O_3-layer with a thickness of 1-9 µm.

2. Cutting insert according to claim 1 characterised in that the κ-Al_2O_3-layer has a thickness of 1-3 µm.

3. Cutting insert according to claim 1 characterised in that the κ-Al_2O_3-layer has a thickness of 4-8 µm.

4. Cutting insert according to any of the preceding claims characterised in that the cemented carbide body has a surface zone 15-35 µm thick depleted from cubic carbides.

5. Cutting insert according to any of the preceding claims characterised in that the cemented carbide has the composition 6.5-8.0 wt-% Co and a CW-ratio of 0.80-0.90.

6. Cutting insert according to any of the preceding claims characterised in that the outermost layer is a thin 0.1-1 µm TiN-layer.

7. Cutting insert according to claim 6 characterised in that the outermost TiN-layer has been removed along the cutting edge.

8. Method of making a turning insert comprising a cemented carbide body and a coating c h a r a c t e r i s e d in that WC-Co-based cemented carbide body with a highly W-alloyed binder phase with a CW-ratio of 0.76-0.92 is coated with

- a first (innermost) layer of $TiC_xN_yO_z$ with a thickness of 0.1-2 μm, with equiaxed grains with size <0.5 μm using known CVD-methods

- a layer of $TiC_xN_yO_z$ with a thickness of 3-15 μm with columnar grains with a diameter of <5 μm deposited by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in a preferred temperature range of 850-900 °C.

- a layer of a smooth κ-Al_2O_3 with a thickness of 1-9 μm.

9. Method according to the previous claim c h a r a c t e r i s e d in that said cemented carbide body has a binder phase enriched surface zone.

10. Use of an insert according to claims 1-7 for turning in hot and cold forged low alloyed steel

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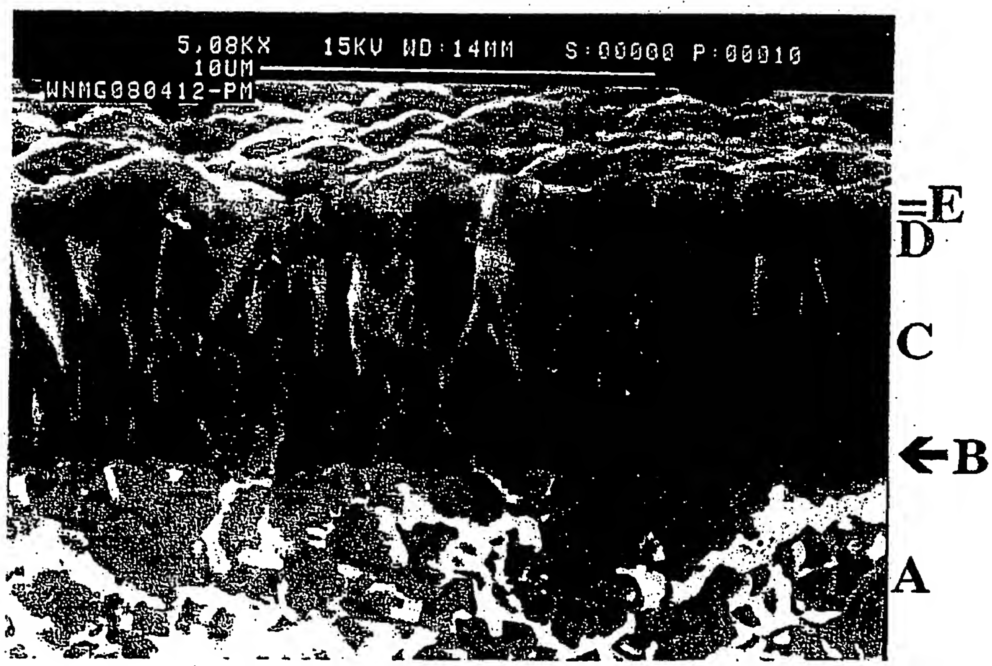

Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
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A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C23C 30/00, C23C 16/30, C23C 16/40, B23B 27/14
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C23C, B23B, C04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	EP 408535 A1 (SECO TOOLS AB), 16 January 1991 (16.01.91), column 1, line 5 - line 23; column 5, line 56 - column 6, line 25	1-10
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Y	Patent Abstracts of Japan, Vol 18,No 392, C-1228, abstract of JP,A,6-108254 (MITSUBISHI MATERIALS CORP), 19 April 1994 (19.04.94), & JP,A,6-108254 (see page 3, line 12-19, page 6 - page 7, page 9, line 12)	1-10
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Y	EP 0594875 A1 (MITSUBISHI MATERIALS CORPORATION), 4 May 1994 (04.05.94), page 13, line 25 - line 35, abstract	4,8,9
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[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
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International application No.
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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X,P	EP 0685572 A2 (MITSUBISHI MATERIALS CORPORATION), 6 December 1995 (06.12.95), page 2, line 55 - page 3, line 29; page 5, line 38 - page 6, line 34, claims 2,4,8,9, abstract --	1-10
Y	Patent Abstracts of Japan, Vol 18,No 203, M-1590, abstract of JP,A,6-8008 (MITSUBISHI MATERIALS CORP), 18 January 1994 (18.01.94) --	1-10
Y	Dialog Information Service, File 351, World Patent Index 81-94, Dialog accession no. 009992182, WPI accession no. 94-259893/32, (MITV) MITSUBISHI MATERIALS CORP: "Surface coated cutting tool - has composite hard layer comprising inner layer of carbide, nitride, carbonitride, oxycarbide and/or carbonitrooxide of titanium ...." & JP,6190605,A, 9432 (Basic) see page 4, line 27 - line 31 --	1-10
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INTERNATIONAL SEARCH REPORT

Information on patent family members

28/10/96

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